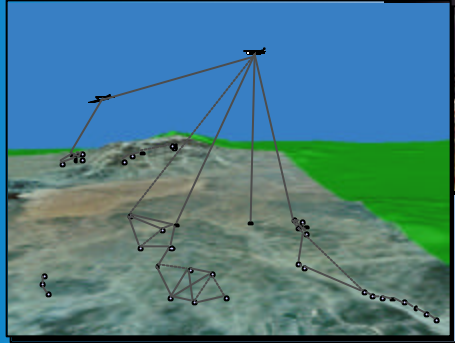


Collaborative Technology Alliance



Communications & Networks



Dr. John W. Gowens
Cooperative Agreement Manager, ARL



**Telcordia
Technologies**

Dr. Ken Young
Consortium Manager, Telcordia Technologies



Communications and Networks Collaborative Technology Alliance



Consortium Partners

- Telcordia Technologies (Lead)
- Network Associates
- BBN Technologies
- General Dynamics
- BAE SYSTEMS
- Georgia Tech
- U of Maryland
- U of Minnesota
- U of Delaware
- Princeton
- Johns Hopkins
- Morgan State
- CCNY
- Clark-Atlanta

Objectives

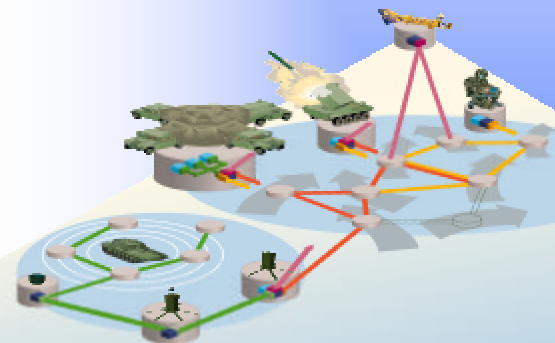
Technologies that enable a fully-mobile, fully-communicating, agile, situation-aware, and survivable lightweight force with internettted C4ISR systems.

Large, heterogeneous, wireless communication networks that:

- Operate while on-the-move with a highly mobile network infrastructure
- Under severe bandwidth and energy constraints
- While providing secure, jam-resistant communications in noisy hostile wireless environment

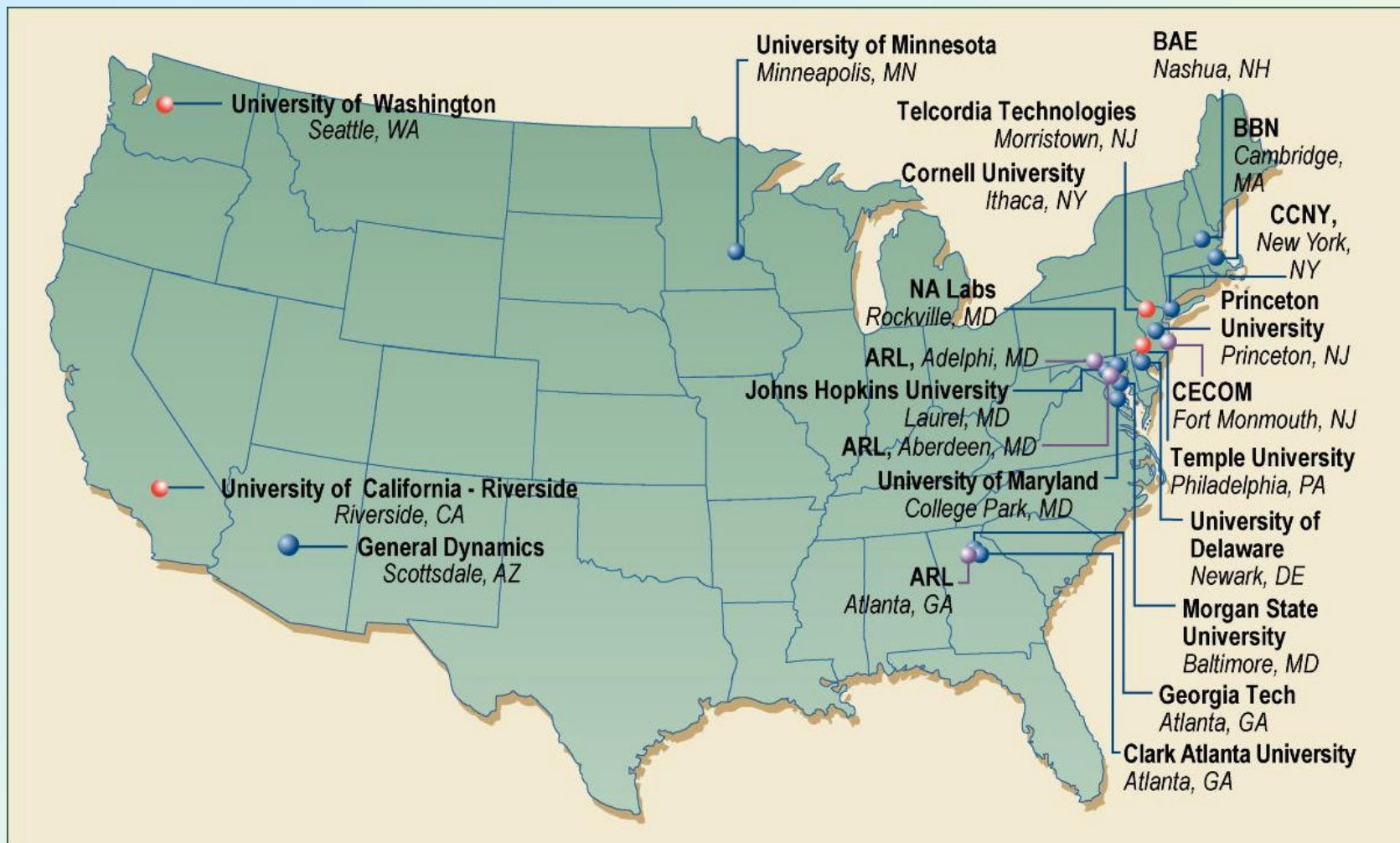
Technical Areas

- Survivable Wireless Mobile Networks
- Signal Processing for Comms-on-the-Move
- Secure Jam-Resistant Communications
- Tactical Information Protection





Member Locations





Communications for Future Combat Systems



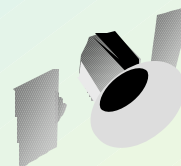
Motivation: To Simultaneously and Reliably Achieve

- High Data Rates for Collaborative C⁴ISR (Network-Centric Operations)
- Low Probability of Detection
- Robustness to Jamming
- Communication-on-the-Move in Highly Dynamic Environments

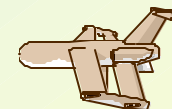
Objective: A fully mobile and lightweight force with internettted C⁴ISR with

- Mobile, ad hoc networks capable of operating with extreme LPD and jamming resistance
- While carrying real-time traffic for positive robotic and fire control

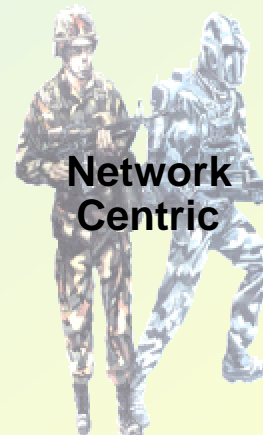
Robotic Indirect Fire



Small Unit UAV



Network Centric



Robotic Direct Fire



Robotic Sensor



C2/Troop Carrier (Dismounts)



Future Combat Systems Communications Notional Approach



A fully mobile and lightweight force with internetted C⁴ISR

- **High-band communications to simultaneously achieve high data rates, LPD, and A/J**
- **Low-band communications to enable interoperability and operate when direct line-of-sight is unavailable due to terrain, foliage, or weather**
- **Directional antennas to meet survivability/throughput requirements**
- **Airborne assets to augment connectivity in highly dispersed operations especially in complex terrain**
- **Diverse communications requirements:**
 - **Command and control/situational assessment data among all nodes**
 - **Sensor data distribution between UAVs, UGSs, and robotics**
 - **Fire control between vehicles and weapons platforms**
- **Many elements will be unmanned with significant risk of capture**



Communication and Networks Collaborative Technology Alliance

PM/DPM: Telcordia, Dr. Ken Young/Dr. Simon Tsang

CAM/DCAM: ARL, Dr. John W Gowens/Mr. Greg Cirincione

Survivable Wireless Mobile Networks

Telcordia, Dr. Ken Young
ARL, Mr. Hal Harrelson

Highly Efficient & Robust Subnet Organization

BBN, Dr. J. Redi
UDel, Dr. E. Lloyd

Autonomous Internetworking

Telcordia, Dr. A. McAuley
JHU, Dr. I-J. Wang

Efficient, Reliable End-to-End Networking

Telcordia, Dr. M. Fecko
UDel, Dr. P. Amer

Network Management for MANETs

Telcordia, Dr. W. Chen
UDel, Dr. A. Sethi

Signal Processing for Comms-on-the-Move

Telcordia, Dr. Joe Liberti
ARL, Dr. Ananthram Swami

Multiple Access

UMinn, Dr. G. Giannakis

Multi-Input Multi- Output Systems

Telcordia, Dr. J. Liberti
UDel, Dr. X. Xia

Cross-Layer and Novel Designs

Ga Tech, Dr. M. Ingram

Secure Jam-Resistant Communications

BAE, Dr. Diane Mills
ARL, Dr. Brian Sadler

Adaptive LPD Processing

Ga Tech, Dr. G. Stüber

Array Processing

UDel, Dr. G. Arce

Frequency-Hopping Systems

GD, Mr. J. Kleider

Tactical Information Protection

NAL, Mr. Dave Carman
ARL, Mr. Greg Cirincione

Highly Efficient Security Services and Infrastructure

NAL, Mr. D. Carman
UMd, Dr. J. Baras

Tactical Intrusion Detection

Telcordia, Mr. M. Little
Ga Tech, Dr. J. Cannady

| | | Telcordia | NA Labs | BBN | BAE | GD | UMd | UDeI | GaTech | UMinn | CCNY | Princeton | JHU | MSU | CAU | ARL |
|---|---|-----------|---------|-----|-----|----|-----|------|--------|-------|------|-----------|-----|-----|-----|-----|
| | <div></div> = Co-PI <div></div> = AI | | | | | | | | | | | | | | | |
| TA1 Survivable Wireless Mobile Networks Telcordia | | | | | | | | | | | | | | | | |
| 1.1 Subnet Organization | | | | | | | | | | | | | | | | |
| 1.2 Auto Internetworking | | | | | | | | | | | | | | | | |
| 1.3 End-to-End Transport | | | | | | | | | | | | | | | | |
| 1.4 Net Mgt for MANETs | | | | | | | | | | | | | | | | |
| TA2 Signal Processing for Comms-on-the-Move Telcordia | | | | | | | | | | | | | | | | |
| 2.1 Multiple Access | | | | | | | | | | | | | | | | |
| 2.2 MIMO Systems | | | | | | | | | | | | | | | | |
| 2.3 Cross-Layer & Novel | | | | | | | | | | | | | | | | |
| TA3 Secure Jam-Resistant Communications BAE SYSTEMS | | | | | | | | | | | | | | | | |
| 3.1 LPD Processing | | | | | | | | | | | | | | | | |
| 3.2 Array Processing | | | | | | | | | | | | | | | | |
| 3.3 FH Systems | | | | | | | | | | | | | | | | |
| TA4 Tactical Information Protection NAI Labs | | | | | | | | | | | | | | | | |
| 4.1 Security Services | | | | | | | | | | | | | | | | |
| 4.2 Intrusion Detection | | | | | | | | | | | | | | | | |



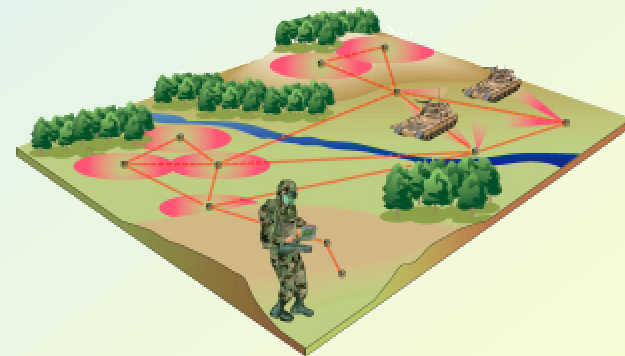
Survivable Wireless Mobile Networks (TA1)



Objective: Dynamically self-configuring wireless network technologies that enables secure, scaleable, energy-efficient, and reliable communications

Challenges:

- Scalability to thousands of nodes
- Highly mobile nodes and infrastructure
- Severe bandwidth and energy constraints
- Decentralized networking and dynamic reconfiguration
- Accommodation of high bit-error-rate, wireless networks
- Seamless interoperability



Scientific Barriers:

- Understanding of trade-offs under bandwidth, energy, processing capability, bit-error-rate, latency, and mobility constraints
- Understanding of interactions between cross-layer algorithms
- Limited modeling capability for scaling distributed algorithms

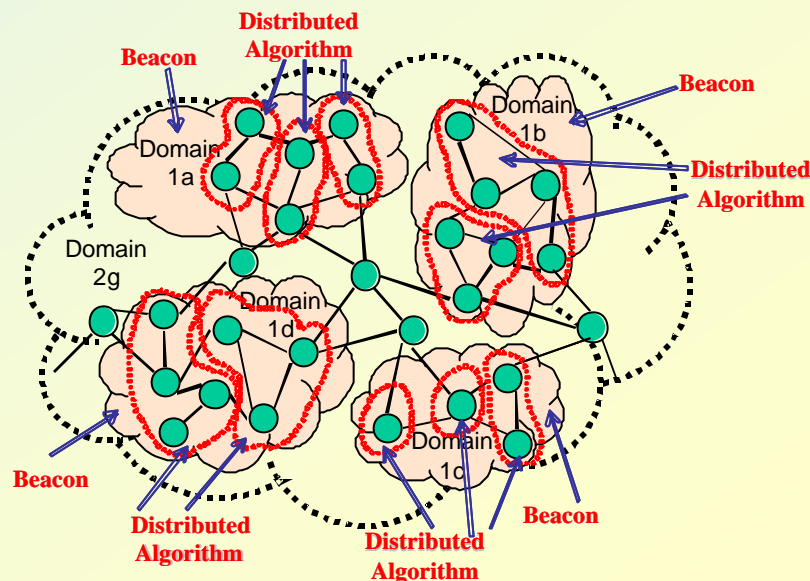
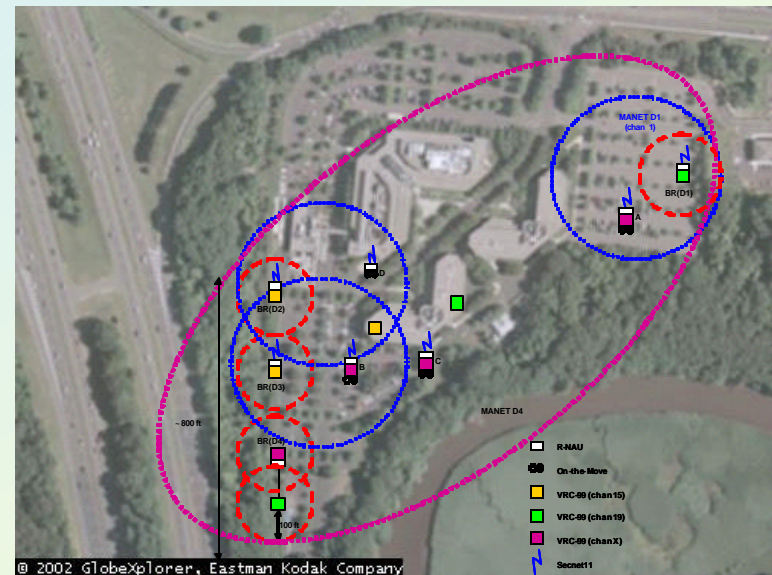


Domain Autoconfiguration

Task 1.2

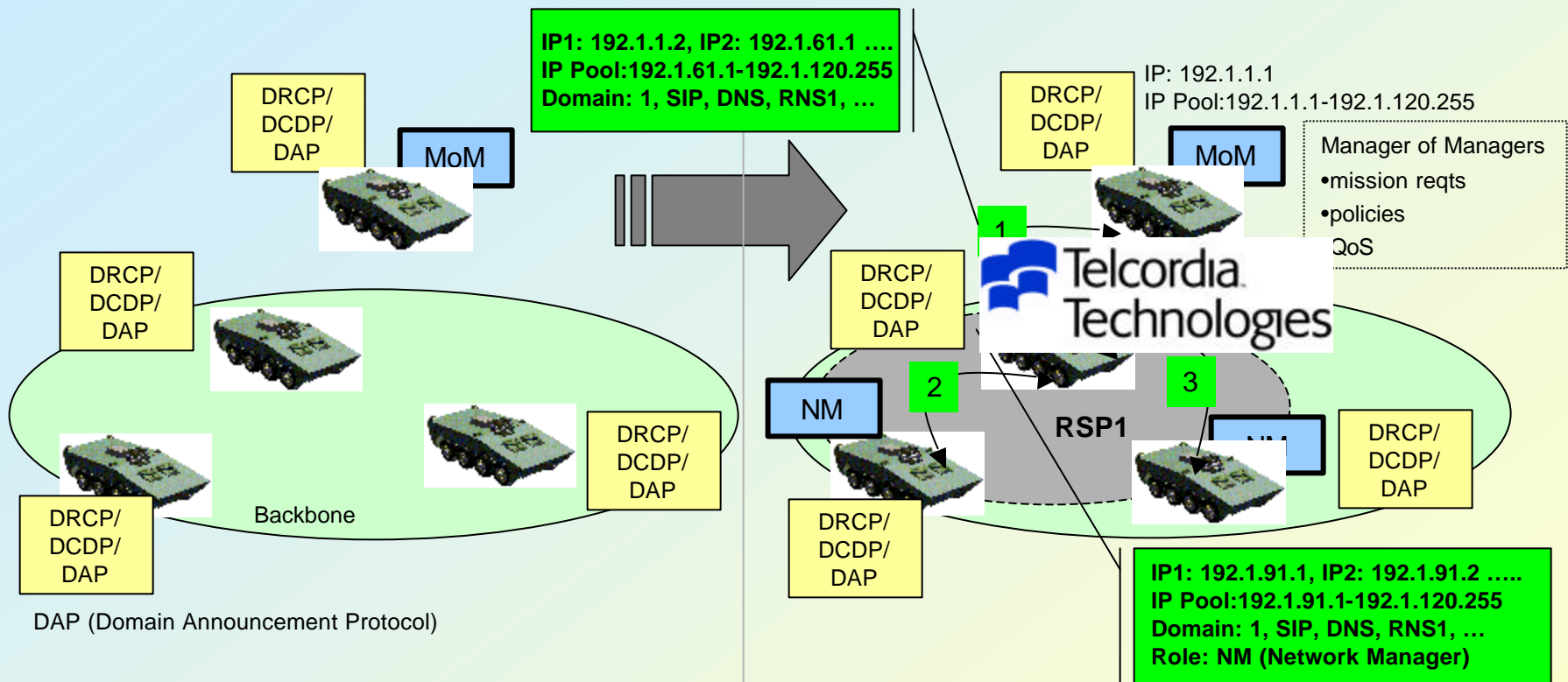


- Scalable, robust protocols to create and maintain domains in dynamic networks
 - DCDP modifications for routing domain autoconfiguration
 - Beacon Protocol (DAP) to maintain domains with network splits and merges
- Algorithms to dynamically decide domain membership based on node mobility, roles, etc.
 - New centralized algorithms that work with Configuration Manager
- Dynamically selecting border nodes
 - Distributed algorithm for border nodes
 - Aggregating domain information
- Isolating and resolving faults and intrusions using domain reconfiguration



Reliable Server Pooling

Task 1.3



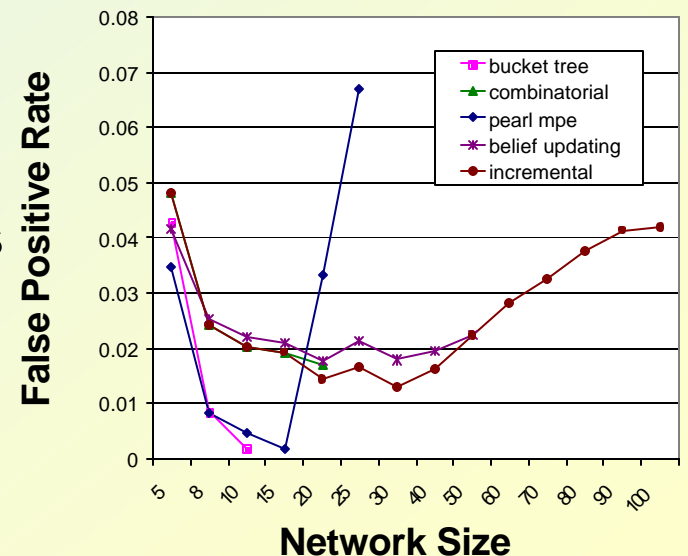
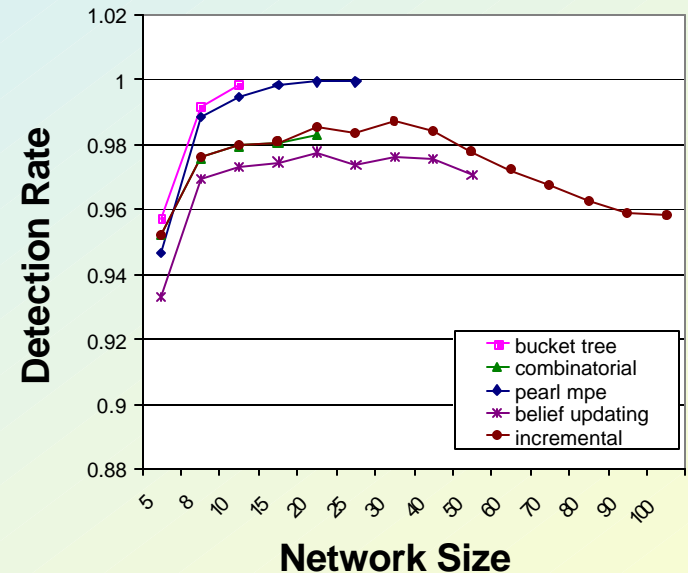
(a) Before auto-configuration of FCS backbone domain 1

- (b) After auto-configuration of FCS backbone domain 1
- Selects multiple NMs and pools them in Reliable Server Pool
 - Other pooled servers include BB, SIP Proxy, DNS, TPKI (Tactical Public Key Infrastructure), etc...
 - Fail-over from one server to another is done using RSP mechanisms

Fault Localization and Self-Healing

Task 1.4

- Layered dependency model
- Non-deterministic fault model
- Localization algorithms
 - Bayesian localization
 - Incremental localization
- Handling imperfect information
 - Inaccurate probability estimates
 - Negative vs. positive information
 - Lost and spurious symptoms
- Decentralized domain-based fault localization
- Interactions with self-healing mechanisms





Signal Processing for Communications-on-the-Move (TA2)



Objective: Signal processing techniques to enable reliable low-power multimedia communications among highly mobile users under adverse channel conditions

Challenges:

- Highly mobile nodes and infrastructure
- Highly diverse dynamic channels and network topologies
- Bandwidth, spectrum, and energy constraints
- Mobile, multi-user, high-speed, variable load/QoS comms
- Low complexity transceiver design: size, weight, and power
- Scaling issues

Scientific Barriers:

- Analytic framework for trade-offs under bandwidth, energy, processing capability, bit-error-rate, latency, and mobility constraints
- Analytical/statistical models for time/frequency selective channels
- Understanding iterative non-linear multi-user turbo algorithms
- Analysis of cross-layer interactions and design



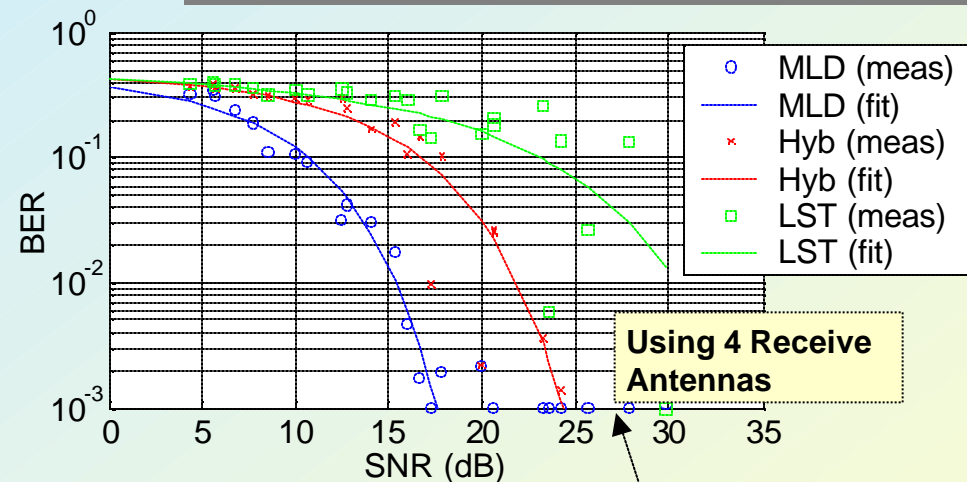
MIMO Demonstration



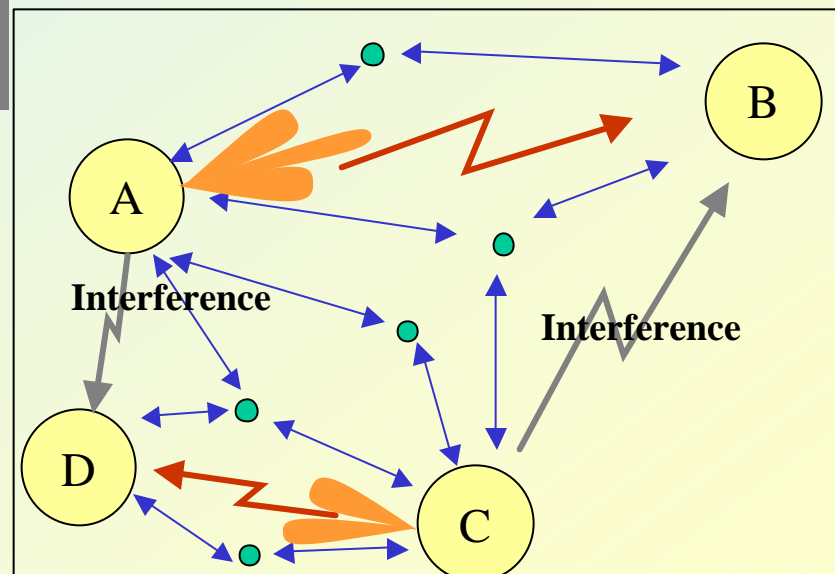
Preparations underway for a large scale multi-node demonstration of functional real-time MIMO technology supporting FCS functionality :

- OFDM Turbo-STTC MIMO with variable spreading factor.
- Iterative Detection to Approach ML Performance
 - Enables use of smaller numbers of Rx antennas compared with traditional techniques.
- Cross Layer Integration
 - Demonstrate impact of MIMO at higher layers
- MIMO Medium Access Control
 - Trade-off capture probability vs burst throughput.

Telcordia's MIMO Transmitter and Receiver used in ARL MIMO measurement campaigns in 2000, 2001, and 2002.



Symbols represent measured data points using OFDM-STTC-MIMO from Telcordia/ARL Spring 2002 MIMO Measurements. Lines are fitted to measured results.



Completed extensive simulations and analyses of multi-node MIMO networks including impact of MIMO on overall network throughput.



Secure Jam-Resistant Communications (TA3)



Objective: Secure, jam-resistant, multi-user communications effective in noisy/cluttered and hostile wireless environments enabling LPD and LPI on-demand

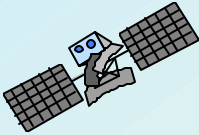
Challenges:

- LPD/LPI/AJ performance under mobile conditions
- Nearby jammers and long haul links
- Spectrum availability
- Smart antenna transceiver complexity
- QoS and high data rate demands
- Co-site interference

Scientific Barriers:

- Signal and packet design for LPI/LPD systems
- Smart antenna algorithms and analysis
- Acquisition/synchronization in a hostile environment
- Adaptive spectrum allocation

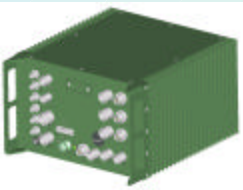
Satellite or UAV Reachback



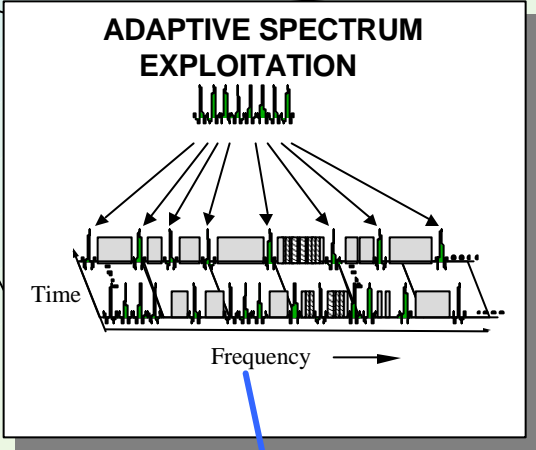
JTRS Spectrum
Scan 1-4 Channels



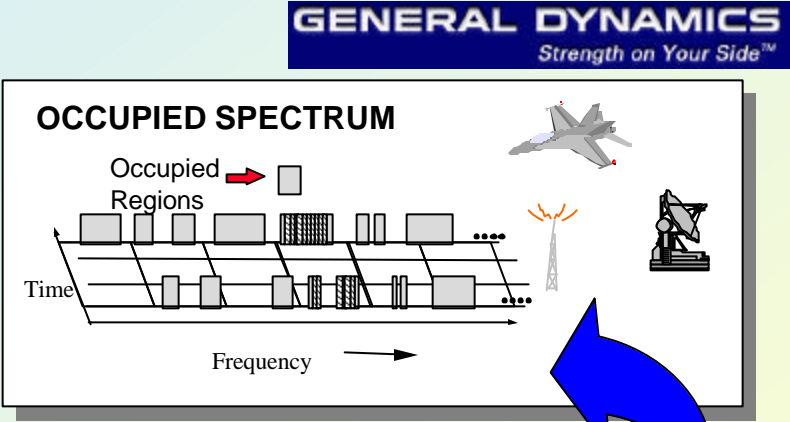
SDR Unit (DMR)



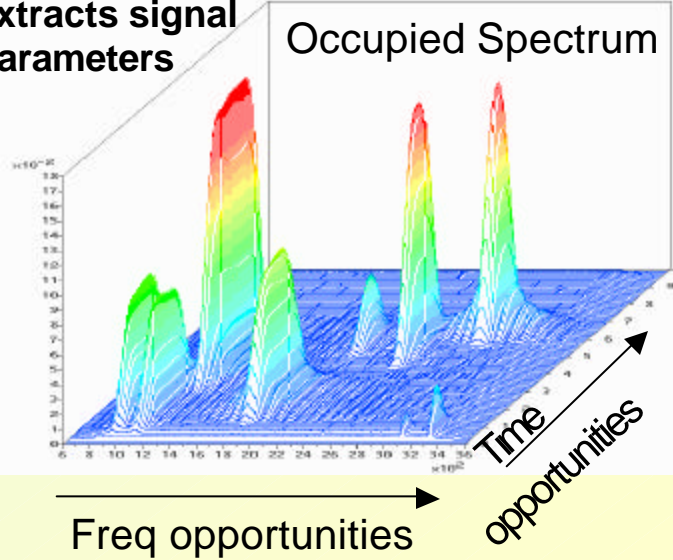
Vehicular SDR Unit
(e.g. Cluster 1)



Adapt Network Waveform
Around Interference, or
use for “other purposes”



Efficient JTF signal analysis
extracts signal
parameters



Processing capabilities of SDR will enable dynamic coordination of hopsets and operating frequencies for ad-hoc wireless networks



Tactical Information Protection (TA4)



Objective: Technologies that provide automated, scaleable, efficient, adaptive, and secure information protection in wireless, multi-hop, self-configuring networks

Challenges:

- Severe bandwidth, energy, and processing constraints
- Accommodation of high bit-error-rate, wireless networks
- Information protection with dynamic addressing
- Lack of concentration points where network traffic can be analyzed
- Significant risk of node capture

Scientific Barriers:

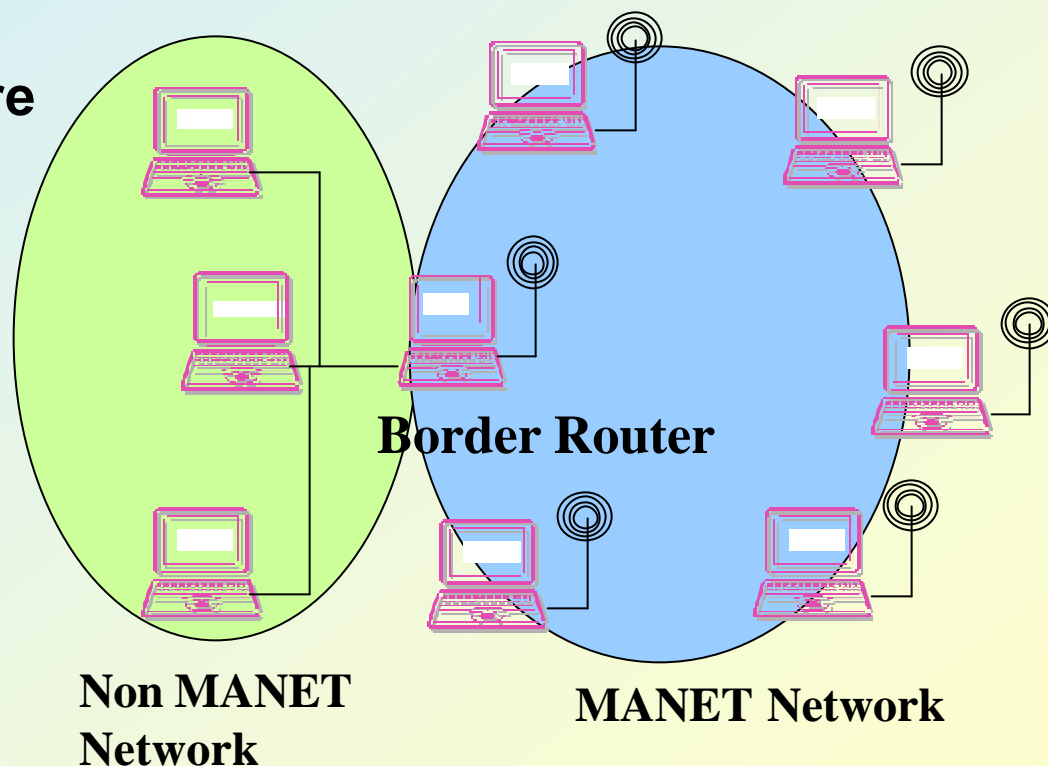
- Understanding of trade-offs under bandwidth, energy, processing capability, bit-error-rate, latency, and mobility constraints
- Understanding of interactions between cross-layer algorithms
- Limited modeling capability for scaling distributed algorithms
- Limited ability to reason about intrusions without high false alarm rates and to detect new forms of attack



Tactical Environment Assurance Laboratory Task 4.2



- Wired and wireless communications infrastructure
- MOSAIC ad hoc mobility protocol environment
- Generative test harness
 - Control network dynamics
 - Control attack timing and sequencing
- Intrusion Detection System instrumentation
- Attack tools
- Synergies
 - CECOM Tactical Wireless Network Assurance (TWNA)
 - Intrusion Detection System for MANETs (6.2 task order)





Technology Program Annexes



- **CE-CI-1999-04:**
Self-Configuring Wireless Mobile Ad Hoc Networks
- **CE-CI-2003-TBD:**
Network Management for Mobile Ad Hoc Networks
- **CE-CI-2003-TBD:**
Multi-Carrier Tactical Waveforms and Processing
- **CE-CI-2002-01:**
Protection of Mobile Code
- **CE-CI-2003-TBD:**
Intrusion Detection System for Mobile Ad Hoc Networks



FY01-03 Accomplishments - 1



- Published or accepted for publication 35 journal papers and 137 conference papers (as of April 2003)
- Thematic workshops
 - Held workshop on Secure Group Communications with 40 attendees (13 March 2002)
 - Joint NSF/ONR/ARO-CTA Workshop on Future Challenges for Signal Processing and Communications in Wireless Networks (5-6 Sept 2002; <http://acsp.ece.cornell.edu/NSF/>)
 - Workshop on mobile networking protocols planned for 2003
- Monthly VTC seminars
 - 23 September 2002 – “Transmit Eigen-Beamforming, Space-Time Coding, and Adaptive Modulation based on Channel Mean-Feedback” – Dr. Georgios Giannakis (U. Minnesota)
 - 31 October 2002 – “Autoconfiguration of IP Hosts in Ad Hoc Mobile IP Networks” – Dr. Raquel Morera (Telcordia)
 - 11 December 2002 – “Bandwidth Efficient Tamper Detection for Mobile Applications” – Dr. Lori Pollock (U. Delaware)
 - 28 January 2003 – “Making Link State Scale for Ad Hoc Networks” – Dr. Cesar Santivanez (BBN)



FY01-03 Accomplishments - 2



- **Staff rotations**
 - Seven between ARL and consortium
 - Six among consortium members
- **HBCU/MI involvement**
 - Participated in 9 of 12 research tasks
- **Technology Transition contracts**
 - Spectrum Awareness – General Dynamics
 - Optical Sensor Networking for Laser Communications and Atmospheric Channel Characterization – UMd
 - 2003 Annual Symposium – Telcordia
 - CECOM DRAMA – Telcordia
 - Intrusion Detection for MANETs – Telcordia/NA Labs
- **Patents: 2 filings, 4 applications, 14 disclosures**
- **2003 Annual Symposium**
 - C&N CTA is lead for 2003
 - 29 April – 1 May 2003 @ University of Maryland University College, Inn and Conference Center
 - Keynote talks, panel sessions, technical talks, posters, exhibits